INFORMATION TECHNOLOGY STRATEGIC PLANNING AS A TOOL FOR ENABLING 21ST CENTURY MISSIONS

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ABSTRACT

Space missions of the 21st Century will be characterized by constellations of distributed spacecraft, miniaturized sensors and satellites, increased levels of automation, intelligent onboard processing, and mission autonomy. Programmatically, these missions will be noted for dramatically decreased budgets and mission development lifecycles. To achieve these future challenges, advanced technology–especially information technology–will provide a critical role for the formulation, implementation and execution of these missions. This paper will discuss a strategic technology planning process and strategic technology program operating plan which the Information Systems Center at the Goddard Space Flight Center recently formulated and implemented.

INTRODUCTION

NASA is entering a bold new frontier in science exploration and technology research and development. After the first four decades of human-tended spacecraft to the moon and near-earth orbit and robotic spacecraft in varying earth orbits and into our solar system, we are planning revolutionary new missions often comprised of constellations of spacecraft to explore these environments and other astronomical items of interest. These missions are characterized by constellations of miniaturized spacecraft, advanced sensors, innovative communication schemes, increased levels of automation, onboard processing, and mission autonomy. Programmatically, these missions will be noted for dramatically decreased budgets and mission development lifecycles. To achieve these future challenges, advanced technology–especially information technology–will provide a critical role for the formulation, implementation and execution of these missions. The process by which we conceptualize, research, develop, validate, and infuse technologies must be dramatically improved and accelerated. Furthermore, it must include provisions and strategies to accommodate rapidly emerging and developing commercial technologies for infusion into space mission systems.

To address the future mission needs, the Information Systems Center at the Goddard Space Flight Center formulated and began implementation of a strategic technology planning process and strategic technology program operating plan. This paper will share our initial experiences with developing this process and lessons learned during our first execution of it. It will include an example from the NASA/GSFC's mission information systems Strategic Technology Plan, technology vision, and roadmap which "seed" research and development activities for NASA missions in response to the NASA Strategic Enterprise plans and "drivers." The three mission information system technology thrust areas which comprise our Strategic Technology Plan are: Rapid Mission Formulation and Development, End-to-end System Autonomy, and Advanced Scientific Tools and Systems. Collectively these groupings of critical mission information system technologies are laying the foundation to enable innovative and less costly missions opportunities for the 21st Century.

GSFC SPACE MISSIONS OF THE 21ST CENTURY

Numerous revolutionary new space missions are in the concept phase of development at the NASA Goddard Space Flight Center. Most are uniquely different from previous missions in complexity, number of spacecraft, configuration, and interaction. The most noteworthy new focus is on missions comprised of multiple miniaturized spacecraft, often flying in formation, enabling multi-point observations from unique vantage points and enabling temporal differentiated measurements.

This shift from traditional single point observations to multipoint observations will be dramatic and will require a broad array of innovative new technologies to provide the needed functionality and to be affordable. Most of these missions require sophisticated automation and autonomy, increased onboard processing of both

Presented at the1999 AIAA Space Technology Conference, Albuquerque, NM September 28-30, 1999

science and engineering data, and automated science feature identification. Innovative new operations concepts and supporting technologies will also be necessary to allow these constellations to be operated in a effective and affordable manner.

Other unique concepts are under study to enable radical new missions in the far term. The Earth Science Vision Team, chartered by the NASA's Earth Science Enterprise, is developing advanced ideas, such as "SensorWebs" of advanced, smart instruments capable of coordinated multipoint observations. More advanced instruments capable of inter-communicating will enable collaborative teams of sensors to perform passive monitoring or even active exploration for improved science data acquisition. Routine autonomous operations, data collection and data synthesis are required to make mission operations manageable cost effective. Innovative data access, analysis, and visualization tools are needed to facilitate science analysis and understanding.

In order to meet its unique mission needs within its constrained budget, NASA commenced a new Program to radically re-engineer its engineering process and toolset. The initiative, called the Intelligent Synthesis Environment (ISE), will enable geographically distributed groups of people, such as engineers, designers, scientists and technology developers to work together collaboratively on a totally electronic design or the space mission or system. ISE will leverage computational intelligence, which will be built into the design environment, to guide the utilization of the vast resources of knowledge and predictive capability that the environment will access. Advanced modeling and simulation capabilities will allow scientists to interact with simulated vehicles and missions so as to study science payload, mission performance and interaction of science requirements with vehicle and mission engineering. Collectively, this advanced engineering environment is targeting a significant reduction in mission formulation and development of future missions and systems.

Underpinning all of these new complex missions and visionary advanced engineering environments are information technologies necessary to provide the capability or functionality to accomplish the objectives. With an increasing role and dependency on next generation information systems, development of "no-surprise software in less time and at reduced costs is becoming an important element for all future system development. This challenge imposes a requirement on our management to be strategic in how we allocate our information system R&D resources.

AGENCY STRATEGIC DRIVERS

Within NASA, there is renewed focus on developing new technologies that will enable missions that would otherwise not be possible. The Agency is making technology investments for generic classes of challenging missions in advance of the formulation of specific missions. Missions will have firm cost caps and will not be approved for development until the enabling technologies have matured. For this reason it is essential to identify and mitigate the largest technological risks and cost drivers early in the technology development lifecycle. To achieve this goal, some strategic drivers defined by the Agency include the following:

- Leverage external technologies and developments
- Focus on "first of a kind" technology development
- Shift from "Technology derived from missions" to "Missions enabled by technology"
- Significantly reduce mission development lifecycle and costs

KEY CHALLENGES

Developing a strategic plan and roadmap for future application of information technologies has not come without its challenges. Some of the key challenges are as follows:

NASA openly "competing" technology funds: While the agency expresses intentions to migrate the NASA civil servant engineers from sustaining and operational activities back into R&D development, corresponding funding sources for technology initiatives have not yet materialized at the local level. To compound the transition, political pressures are directing up to 75% of NASA technology research funds into a full and open competitive process, and many of the opportunities are closed to NASA employees.

Advent of Full Cost Accounting: NASA is in the process of changing its budget management and accounting procedures. The "before" approach was one in which Headquarter technology-oriented funding sponsors distributed prescribed sums to each field center. The R&D activity and application of new technologies was predominately left to the discretion of the centers. Missions are now accountable for staying within a defined budget and are responsible for funding any advance technology required for their mission within this budget allocation. The challenge is how to encourage infusion of new technologies when a cost-

capped project's risk analysis is going to favor solutions using proven, no-surprise technologies.

Requirement for "marketing" skills: With a previously affirmed budget for in-house R&D initiatives, the "hands-on" technologists were able to dedicate all of their energies into development and invention of new technologies. They were sheltered from the rigor of preparing a competitive proposal to secure investment funds. In the new environment of competing with other NASA centers and private research labs for technology funding, we have the challenge of teaching and motivating technologists on how to develop and write winning proposals, including "marketing" their ideas and preparing cost benefit analysis.

Fast pace of emerging information technology: The rapid evolution and revolution of information technologies requires a high awareness of the latest advances, the ability to continual refresh a workforce's technology knowledge base, and an agility to quickly change direction based on technology shifts. The challenge of how to ensure a dynamic "information refresh" capability within an organization, given growing cost constraints, becomes a critical factor in developing a potent technology strategic plan.

New push to partner with industry: As a means of fostering transfer of technologies and knowledge between NASA and industry, NASA has been encouraging its workforce to develop working partnerships with industry leaders. The desired partnership model, which creates the most interesting challenges, is one in which both NASA and a private company bring resources "to the table" and jointly invest in a technology project. These partnerships raise issues of intellectual property rights, which become even more challenging for software. A software product is not tangible and the understanding of what is intellectually protected is still in its infancy. The situation then arises of how to craft the legal agreements to protect the government employees' rights, the private company's proprietary rights, and the taxpayer's rights to NASA information (e.g., via the Freedom of Information Act.) This challenge becomes even more daunting when you consider the speed with which software technology becomes obsolete, and yet, the legal profession is not generally recognized for its expediency.

Meeting current commitments: As NASA strives towards increasing its level of new, advanced technology initiatives, the challenge of balancing the requirement to meet current customer commitments against the need to increase the amount of new technology opportunities creates a volatile work environment. With the agency's push to "do more with less," a challenge arises as to how to increase the productivity level and quality of support to current customers, while beginning to shift some resources to new R&D initiatives.

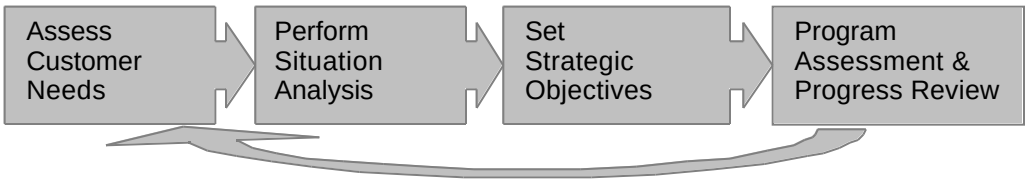
Competition in the marketplace: At one time NASA did not have to be particularly concerned about retention of its workforce. If you desired employment in aerospace, the ultimate employer was NASA. There is still a certain aura associated with being a NASA employee. However, the increase in commercial companies in telecommunications and satellite development, combined with today's "hot" market for IT professions, has made it challenging for NASA to attract and retain top professional talent.

ISC'S STRATEGIC TECHNOLOGY PLANNING PROCESS

The ISC Strategic Technology Program was established to identify and develop key mission information system technologies needed by our key science and mission customers. A simple, high-level process was followed to insure a comprehensive and objective assessment of our customer needs, the internal and external environment, and strategic drivers.

Assess Customer Needs- One of the most important steps consists of gathering and analyzing customer's needs, expectations, and plans. This step entails intelligence gathering via formal and informal means, e.g., organization plan analyses, customer focus groups, face-to-face meetings, hallway conversations, etc. It is important to fully understand and internalize customer's objectives, priorities, and explicit technology needs, both near and far term, to prepare your own organization to better meet and, ideally, anticipate their needs.

Perform Situation Analysis- There are two essential elements for situation analysis- internal and external. The first is inward looking and consists of assessing the organization's core competencies (current & desired), strengths & limitations, drivers and values. The second focuses on the identification and assessment of the external environment and consists of alternative service



providers, market and technology trends, and funding or programmatic opportunities. The purpose of situation analysis is to provide just enough information to make good decisions about your strategic objectives and directions.

Set Strategic Objectives- The primary purpose of this step is to gain consensus on the organization's strategic priority issues and objectives. For an organization, this is conventionally stated in terms of "mission, vision, values." Since our goal was to identify strategic direction and priorities for our technology program, we identified a critical few technology focus areas, long-term visions for each, and an integrated "technology capability roadmap"- a phased progression of technology capabilities necessary to achieve the technology focus area visions.

Establish Action Plan/Implementation Strategies- Once a consensus is achieved on the strategic objectives, approaches for achieving them must be made. Using the information gathered in the situation assessment, strategies must be established to eliminate barriers, address weaknesses and limitations, and leverage strengths to exploit opportunities all in pursuit of the agreed-upon "strategic objectives."

LESSONS LEARNED

Having nearly completed the first full cycle through our Strategic Technology Planning Process, we have taken time to conduct a retrospective assessment of the activity and results to identify some successes and areas for improvement. We offer the following as 'lessons learned' in the hope that you will benefit from our experiences to date.

Simplify. Simplify your process, analysis, results and communications to the level that is both effective and meaningful. Too much detail is overwhelming and not absorbed by the very audience you are trying to influence; too little detail may be taken as unsubstantiated and shallow in concept and context. Keep in mind that the purpose of strategic planning is to focus the organization's efforts and channel the workforce's energies in a planned direction.

Avoid making strategic planning into yet another paperwork exercise. Keep paperwork sparse, documenting only the information and analysis needed to make correct key decisions and to communicate your plan and implementation strategies. Use communications forms that are customized and most effective for your target audiences. Websites are particularly ideal for getting up-to-date information to a large organization quickly. However, balance this form with other methods- verbal, presentations, and executive summaries.

Minimize rework and leverage results from external sources. For the environmental analysis, try to reuse analysis results from other groups, both within your company and outside, especially when directly applicable to your assessment. Also, some commercial companies, e.g., PriceWaterhouseCoopers and GartnerGroup, offer excellent market assessments and forecasts that may be beneficial for your analysis purposes.

Employ a balanced top-down/bottom-up approach. A strictly top-down plan often lacks buy-in or technical credibility. Successful plans require the involvement, commitment, and realistic input from employees at all levels of the organization. This must include the organization's senior manager who must provide clear direction, leadership, and commitment to the strategic plan from the top down.

Use a diverse team. A good planning team requires diverse perspectives. Strive for a mix of visionary and technically grounded individuals, details-oriented and big picture, and variety in experience levels, disciplines (within your organization), thinking styles, gender, culture, etc.

Secure buy-in of final product from management, customers & stakeholders. To assure that your intermediary or final plan is on course, host pre-release feedback sessions. These sessions can be instrumental in helping you tailor your message during your formal rollout sessions to your management team, customers, and stakeholders. Also consider using an external group as a "sounding board" and reality check.

Beware of "Analysis Paralysis" Thoughtful, fact-based plans work. Those based on wishes or assumptions don't work. It is necessary to gather the facts and assess your current situation but don't over-analyze. Most real and substantial issues exist at the "gut level" and are easily identified by asking the right questions. Attempt to keep the analysis quick and simple.

Limit the activity duration- but allocate sufficient time. It is easy to want to perfect the strategic plan. This could lead to extending the team's schedule to accommodate such desires. Plans can always be tweaked and polished. Establish an aggressive but realistic schedule to execute your strategic planning process. Your outputs should be considered a "living document" that provide specific direction for the organization

Obtain customer and stakeholder inputs early and often BUT don't use this as only driver. Securing customer and stakeholder inputs to strategic planning are critical. Strive to seek their ideas early and frequently however, do not accept it as the only input. Their perspectives may be focused on their more immediate needs and an unawareness of your other customers, commitments or external factors. You must balance what is optimal for meeting your customers needs and expectation, and for ensuring your organization's long-term viability and vitality.

Have frequent intermediate status updates. If the planning process is taking more than a few weeks don't keep the intermediary results a secret. Periodically host brief interim communications sessions with key managers for concurrence on direction and to maintain awareness and enthusiasm. However, don't barrage them with details; keep your messages short and to the point. Focus on "what's in this for them" and use poignant questions or issues to engage audience and foster feedback. Also consider using external groups for an external perspective and as a "sanity check."

Focus on capabilities sought versus discrete technologies. We believe it most effective to state the elements of the technology plan in the form of capabilities as opposed to discrete technologies. This will not only prevent rapid obsolescence (which is further compounded by the rapid pace of IT change), but it also prevents predetermining specific solutions as simple incremental evolution of current technologies and thereby prematurely and inadvertently disqualifying other emerging or revolutionary solutions.

Show clear relevance to stakeholders. The results from strategic planning must be relevant to the customers/stakeholders and understood by those who must execute. Avoid techno-jargon as well as management-speak; if unavoidable, translate your message into their terminology. Use language and presentation styles that are most effective to communicate your message to your target audience.

Communicate. Error on the side of overcommunication: to reinforce alignment and maximize acceptance, communicate the organization's mission, priority issues, and strategic objectives on every possible occasion. Tailor the message to the audience making it relevant and clarifying their role and contribution.

Establish and Maintain priority of SP. When developing a strategic plan, 'time to think' is critical. Schedule and use sufficient focused time. In today's environment of overcommitments and "doing more with less", it is too easy to be distracted or overtaken by other crises or activities.

Create measurable performance metrics. Plans can sound great but be of little value without methods to measure how well you are meeting your objectives. Identify and track key performance measures that show clear traceability to your strategic objectives. This will provide valuable input to the evolution of your plan and identifying areas for process improvement.

Strategic Technology Planning is a Continual Learning Process. It is too tempting to expect the results from strategic technology planning to be immediate and perfect. Keep in mind that it is also a learning process in developing a more detailed awareness and understanding of the organization and its capabilities, and in identifying and exploiting opportunities within a cooperative planning environment. Accept the fact that the resulting strategies and objectives will not be perfect and will require adjustments in light of unexpected constraints, opportunities and, possibly, failed implementations. *Note that this is not justification for not investing in strategic planning; strategic planning still offers substantial advantage for preparing the organization and management for "strategic thinking" and "opportunistic decision making" which is the effective reaction to unexpected events and opportunities.*

GSFC MISSION INFORMATION SYSTEMS STRATEGIC PLANNING RESULTS

As an outcome of our strategic planning process, we identified three mission information system technology thrust areas: Rapid Mission Formulation and Development, End-to-end System Autonomy, and Advanced Scientific Tools and Systems. For each of these areas, we identified the following long-term visions:

Rapid Mission Formulation, Design & Execution: Enabling revolutionary mission concepts through rapid mission formulation, implementation and execution
Vision: Mission scientists and engineers seamlessly evolve science objectives into mission concepts through virtual model to an operational science system

End-to-End System Autonomy: Enabling effortless science collection through autonomous mission systems
Vision: Mission scientists operate, maintain and reconfigure systems from anywhere in order to optimize an on-board observation and maximize science return

Advanced Scientific Analysis Tools & Data Systems: Enabling science knowledge discovery through seamless and transparent access to information

Vision: Academic and research community has continuous and transparent access to data and information for scientific research

We then defined a snapshot of a phased progression of technology capabilities which, from today's perspective, are necessary to achieve the focus area's visions.

All on-going and proposed technology projects require review and assessment against the vision and technology roadmap to determine their alignment with the strategic directions. A full inventory of technology initiatives is maintained and put on a review cycle to reassess and check on progress and continued relevance. It is during this reassess phase that decisions to continue, redirect or terminate projects are made.

EXAMPLES OF ISC TECHNOLOGIES RESPONSIVE TO TECHNOLOGY ROADMAP

The following are examples of advanced technologies under development in support of ISC's new technology vision. Collectively these critical space technologies are laying the foundation to enable innovative and less costly missions opportunities for the 21st Century.

Advanced Scientific Analysis Tools & Data Systems

- Scientist's Expert Assistant: Develop and infuse a tool to assist scientists in proposal specification for Hubble Space Telescope, in order to determine potential capabilities, limitations, and implementations for the next generation space telescope.
- InVision: Develop and deliver data visualization products in support of science and engineering needs. Research advanced IS technology concepts in data visualization.

Rapid Mission Formulation, Design & Execution

- Operating Missions as Nodes on the Internet: Prototype and infuse a secure end-to-end system embodying the concept of building an architecture in which a spacecraft is considered a node on the internet , which can be operated by a scientist via the Web.
- Instrument Remote Control: Develop, infuse and transfer an advanced system for directly commanding remote instruments, and subscribing to data from remote instruments.

End-to-End System Autonomy

- ComPASS (Common Planning and Scheduling System): Develop, infuse, and transfer an advanced planning system for future missions to serve as an end-to-end (science to mission) integrated tool for scientists which handles science-goal driven, distributed, autonomous on-board adaptive planning and scheduling.
- Agents: Research intelligent agents and apply them in applications for mission operations autonomy
- Spacecraft Emergency Response Collaborative Environment: Research, develop, infuse, and transfer technology to enable distributed mission control.

CONCLUSION

NASA is facing an exciting period in its history where revolutionary new missions are under formulation. Innovative, first-of-a-kind technologies are needed to support this revolution.

Strategic Technology Planning is an invaluable process for research and technology organizations. It provides a systematic approach to identify and analyze the requirements and signals coming from customers and external environment for the purpose of crystalizing key technology capability needs. This allows an organization to secure agreement from customers, stakeholders, and partners on the directions and general priorities of research and technology activities. It also will provide clear guidance for direction and assessment of technology priorities. With equal importance, it will help prepare your organization and management to operate more strategically and be more effective in achievement of its mission and utilization of its resources.